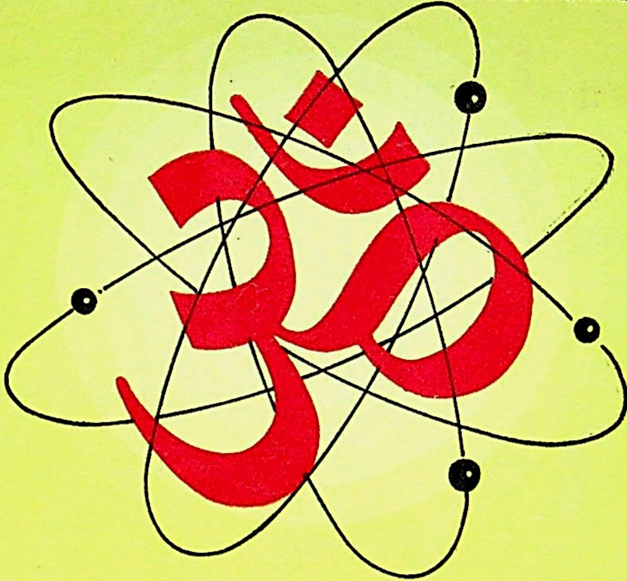
BHAVAN'S BOOK UNIVERSITY



SANSKRIT AND SCIENCE

Dr. Raja Ramanna

SUBODH NARVEKAR



BHARATIYA VIDYA BHAVAN, BOMBAY 400 007.

What Bharatiya Vidya Stands for

Bharatiya Shiksha must ensure that no promising young Indian of oharacter having faith in Bharat and her culture Bharatiya Vidya should be left without modern odeucational equipment by reason merely of want of funds.

2, Bharatiya Shiksha must be formative more than informative, and cannot have for its end mere acquisition of knowledge. Its legitimate sphere is not only to develop natural talents but so to shape them as to enable them to absorb and express the permanent values of Bharatiya Vidya.

3. Bharatiya Shiksha must take into account not only the full growth of a student's personality but the totality of his relations and lead him to the highest self-fulfilment of which he is capable.

4. Bharatiya Shiksha must involve at some stage or other an intensive study of Sanskrit or Sanskritic languages and their literature, without excluding, if so desired, the study of other languages and literature, ancient and modern.

5. The re-integration of Bharatiya Vidya, which is the primary object of Bharatiya Shiksha, can only be attained through a study of forces, movements, motives, ideas, forms and art of creative life-energy through which it has expressed itself in different ages as a single continuous process.

6. Bharatiya Shiksha must stimulate the student's power of expression, both written and oral, at every stage in accordance with the highest ideals attained by the great literary masters in the intellectual and moral spheres.

7. The technique of Bharatiya Shiksha must involve—

(a) the adoption by the teacher of the *Guru* attitude which consists in taking a personal interest in the student; inspiring and encouraging him to achieve distinction in his studies; entering into his life with a view to form ideals and remove psychological obstacles; and creating in him a spirit of consecration; and

(b) the adoption by the student of the *Sishya* attitude by the development of—

(i) respect for the teacher,

(ii) a spirit of inquiry,

(iii) a spirit of service towards the teacher, the institution, Bharat and Bharatiya Vidya.

8. The ultimate aim of Bharatiya Shiksha is to teach the younger generation to appreciate and live up to the permanent values of Bharatiya Vidya which is flowing from the supreme art of creative life-energy as represented by Shri Ramachandra, Shri Krishna, Vyasa, Buddha and Mahavira have expressed themselves in modern times in the life of Shri Ramakrishna Paramahamsa, Swami Dayananda Saraswati, and Swami Vivekananda, Shri Aurobindo and Mahatma Gandhi.

9. Bharatiya Shiksha while equipping the student with every kind of scientific and technical training must teach the student, not to sacrifice an ancient form or attitude to an unreasoning passion for change; not to retain a form or attitude which in the light of modern times can be replaced by another form of attitude which is a truer and more effective expression of the spirit of Bharatiya Vidya; and to capture the spirit afresh for each generation to present it to the world.



आ नो भद्राः क्रतवो यन्तु विश्वतः ।

Let noble thoughts come to us from every side

—Rigveda, I-89-i

BHAVAN'S BOOK UNIVERSITY

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S. RAMAKRISHNAN

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KULAPATI'S PREFACE

The Bharatiya Vidya Bhavan—that Institute of Indian Culture in Bombay—needed a Book University, a series of books which, if read, would serve the purpose of providing higher education. Particular emphasis, however, was to be put on such literature as revealed the deeper impulsions of India. As a first step it was decided to bring out in English 100 books, 50 of which were to be taken in hand almost at once.

It is our intention to publish the books we select, not only in English, but also in the following Indian languages : Hindi, Bengali, Gujarati, Marathi, Tamil, Telugu, Kannada and Malayalam.

This scheme, involving the publication of 900 volumes, requires ample funds and an all-India organisation. The Bhavan is exerting its utmost to supply them.

The objectives for which the Bhavan stands are the reintegration of Indian culture in the light of modern knowledge and to suit our present-day needs and the resuscitation of its fundamental values in their pristine vigour.

Let me make our goal more explicit !

We seek the dignity of man, which necessarily implies the creation of social conditions which would

allow him freedom to evolve along the lines of his own temperament and capacities; we seek the harmony of individual efforts and social relations, not in any makeshift way, but within the framework of the Moral Order; we seek the creative art of life, by the alchemy of which human limitations are progressively transmuted, so that man may become the instrument of God, and is able to see Him in all and all in Him.

The world, we feel, is too much with us. Nothing would uplift or inspire us so much as the beauty and aspiration which such books can teach. In this series, therefore, the literature of India, ancient and modern, will be published in a form easily accessible to all. Books in other literatures of the world, if they illustrate the principles we stand for, will also be included.

This common pool of literature, it is hoped, will enable the reader, eastern or western, to understand and appreciate currents of world thought, as also the movements of the mind in India, which though they flow through different linguistic channels, have a common urge and aspiration.

Fittingly, the Book University's first venture is the *Mahabharata*, summarised by one of the greatest Indians, C. Rajagopalachari; the second work is on a section of it, the *Gita* by H. V. Divatia, an eminent jurist and a student of philosophy. Centuries ago, it was proclaimed of the *Mahabharata* : "What is not in it, is nowhere." After twenty-five centuries, we can use

the same words about it. He who knows it not, knows not the heights and depths of the soul; he misses the trials and tragedy and the beauty and grandeur of life.

The *Mahabharata* is not a mere epic; it is a romance, telling the tale of heroic men and women and of some who were divine; it is a whole literature in itself, containing a code of life, a philosophy of social and ethical relations, and speculative thought on human problems that is hard to rival; but, above all, it has for its core the *Gita*, which is, as the world is beginning to find out, the noblest of scriptures and the grandest of sagas in which the climax is reached in the wondrous Apocalypse in the Eleventh Canto.

Through such books alone the harmonies underlying true culture, I am convinced, will one day reconcile the disorders of modern life.

I thank all those who have helped to make this new branch of the Bhavan's activity successful.

Kanaiyalal Munshi

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FOREWORD

I am glad to find that the Bharatiya Vidya Bhavan has brought out this small book : *Sanskṛit and Science* by our esteemed atomic scientist, Dr. Raja Ramanna. It was the theme of a lecture by Dr. Raja Ramanna, under the auspices of the Bharatiya Vidya Bhavan, Bombay, last year, at which I had the privilege to preside. The lecture created a deep impression on the people present, some of whom were knowing for the first time that this great language, well known as the medium of communication for religious and philosophical ideas, was also an effective medium for communication of scientific ideas, including abstruse mathematical ones.

The learned author first deals with Sanskrit as a language and Panini's scientific treatment of it, and then discusses, with illustrations, its use as a medium to communicate scientific ideas during a period of nearly three thousand years. Dealing with Brahmagupta's mathematics, Dr. Raja Ramanna says: 'Brahmagupta lived in seventh century A.D. This type of equation, with interpolator, later came to be known as Pellian equations. John Pell lived in seventeenth century A.D. while, a thousand years earlier, such equations were dealt with with accurate terminology in India.'

The learned author also deals with the history of Indian scripts and presents a proposal for the reform of our scripts, with illustrative tables.

We are witnessing today a general awakening of interest in our Sanskrit and diverse means for its popularisation; I have also marked increasing interest in this great language in various countries abroad. At this time, this book is a timely publication. Our people will be inspired to read the following tribute to Sanskrit by the late Will Durant, American historian and philosopher, given in his book, *the Case for India*, written in the 1930's to plead for independence for India (p. 4) :

'Let us remember ... that India was the motherland of our race, and Sanskrit the mother of Europe's languages; that she was the mother of our philosophy; mother, through the Arabs, of much of our mathematics; mother, through Buddha, of ideals embodied in Christianity; mother, through the village community, of self-government and democracy. Mother India, is, in many ways, the mother of us all.'

Ramakrishna Math,
Hyderabad

Swami Ranganathananda

PREFACE

It gives me great pleasure to be here today to speak on *Sanskṛit and Science* and share my thoughts with all of you on this important occasion of the "Sanskrit Day". I am, indeed, very grateful to Shri S. Ramakrishnan of Bharatiya Vidya Bhavan for having given me this opportunity.

I am grateful to Dr. Sachidananda Das and Dr. B. V. Subbarayappa for their help in the preparation of this lecture.

Bombay
August 4, 1982

RAJA RAMANNA

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Chapter I

SANSKRIT AS A LANGUAGE

It is generally believed that Sanskrit is a language like any other except that it is more complicated, and dead for all purposes. At best, people are willing to admit that it has a great literature and a cultural value. At the other end, there are people who consider it as a mysterious combination of words to create a religious atmosphere through prayers, chantings, incantations, etc. But, Sanskrit is much more than that, and possesses within itself many of the attributes of a great and useful language. It is both a science and an art combined in one.

Sanskrit Grammar and Pāṇini

Sanskrit has a scientific base which no other language in the world has including Greek and Latin with whom it has close affinity both in vocabulary and grammar (e.g., the word 'axle' in English is 'akṣa' in Sanskrit, 'ἄξων' in Greek and 'axis' in Latin). This is largely due to its grammatical organisation, particularly the Pāṇinian tradition as formulated by Pāṇini in his book, the Aṣṭādhyāyī[1]. Written about 2500 years ago

and divided into eight books (अष्ट अध्याय) of four chapters (पाद) each, Pāṇini's book is one of the greatest exhibits of human intellect. It is the first attempt in the history of the human mind to make a sort of "chemical analysis" of a language on scientific lines (शब्दानुशासनम्). His grammar is not only considered a masterpiece of close reasoning and artistic arrangement, but remains till today unsurpassed in its economy of words to describe linguistic features.

There exists a close parallel between the grammar of Pāṇini and the geometry of Euclid. Just as Euclid, in his *Elements*, starts with a few definitions, axioms and postulates and then goes on building theorems one after the other—more or less tautological since without one the other cannot exist—in a very logical way, in an exactly similar manner, Pāṇini has built up the Sanskrit language. He starts with a few roots† which embody certain general concepts, and defines words which can be a vowel, a consonant, a noun, a pronoun, a person, an augment, a verb, etc., and groups them into various classes. Then he prescribes rules to construct words from roots and affixes (suffixes plus prefixes), compound words from words, and compounds from compounds till an almost interminable chain of derivatives*—similar to analytic continuation of a function in mathematics—is evolved. Thus from the root गम् are derived the words : Gata, Gati, Gatvara, Gantavya, Gamana, Gamayitṛi,

† In Sanskrit language, there are more than 1700 distinct roots or Dhātus. According to some, it might be possible to reduce these roots to a smaller and simpler catalogue of primitive roots whose number does not exceed 120.

* Sanskrit is the only language which, in principle, allows no hiatus in a sentence. This has been made possible by the rules of sandhi (euphonic combination).

Gamanikā, etc. Pāṇini has squeezed and distilled his thoughts and has put them in the form of a little under 4000 short *sūtras* or aphoristic rules which fall into six types : संज्ञा (definition), परिभाषा (key to interpretation), विधि (statement of a general rule), नियम (a restrictive rule), अधिकार (governing rule) and अतिदेश (extended application by analogy).

In Sanskrit grammar, the various affixes play key roles in assigning meaning to a word structure depending upon composition; choice of an affix being itself dictated by the nature of information to be transferred. The construction is accordingly defined. For example, the affix यत् coming after the word नौ (a boat) in Instrumental case in construction means "to be crossed." Thus the word नाव्यम् (नावा तार्यम्) means 'what can be crossed by a boat', i.e., 'water', 'a river'. However, the very same affix when placed after a word in the locative construction, has the sense of 'excellent in regard thereto' as in सामन्यः (सामसु साधुः) which means 'conversant with the Sāma-Veda'. Here, साधु does not mean उपकारक (a benefactor or a good person) but प्रवीण, or योग्य (expert or fit). Yet another example is that of the radical element प्र which in composition with a verb is an upasarga or preposition as in प्रणायकः meaning 'a leader'; same प्र in composition with a noun is a Nipāta as in प्रनायकः which means 'destitute of a leader.' In this manner, information—a physical quantity connected with entropy and thermodynamics[2]—is transferred with a minimum of economy in words. Simultaneously, euphony (phonetics) is also maintained.

Sanskrit Phonetics

It is interesting to know that phonetics as a science is entirely Sanskritic and has been studied with such

great depth and accuracy that it would amaze a modern scientist. An analysis has been made of what is a vowel, what is a consonant, what are nasals, what are homogeneous letters, etc., on the basis of where the tongue goes, what is it that vibrates, what are the organs of speech that participate (and to what extent) in producing a letter sound, etc. For example, a vowel is one that rubs along and produces sound depending on the shape of the mouth. The dental न and the cerebral ण depend upon the depth to which the tongue is turned. Homogeneous (सवर्ण) letters are those whose आस्य or place of pronunciation (कण्ठ "throat", तालु "palate", मुर्द्धा "head", दन्ताः "teeth", ओष्ठौ "lips", नासिका "nose"), and प्रयत्न or effort are equal. Thus च and श, though have the same आस्य, i.e., तालु are not savarṇa because their प्रयत्न is different; the प्रयत्न of च is sprishṭa (complete contact of organs, i.e., tongue with throat, palate, dome of the palate, teeth and lip) and that of श is vivṛita or complete opening. Similarly, क and च though have the same प्रयत्न, i. e., sprishṭa, are not savarṇa because their आस्य is different, one being guttural and the other palatal. Nasals (अनुनासिकः) are defined as those letters which are partially uttered by the nose and partially by the mouth (मुखनासिकावचनो). This makes ङ, ञ, ण, न and म nasals but not the consonants क, च, ट, त, प, etc., since the latter are pronounced wholly and solely through the mouth. Anusvāra is not nasal as it is pronounced wholly through the nose (pure nasal). In Sanskrit, words—single or compound—have different meanings depending on the position of the accent.

Form and Growth of Sanskrit

Because Sanskrit grammar is so thorough and precise, the form of the language is well defined, orderly

and perfect. In fact, Sanskrit literature follows such beautiful and accurate mathematical patterns that one marvels at them. Even the Greeks cannot claim such regularity.

Sanskrit has also the power of organised growth since it is developed in a most mathematical and logical way—like geometry is developed—from roots and certain combinations prescribed by rules so that roots can be added to and shortened to produce new word structures. However, this procedure of generating Sanskrit language from roots according to well laid linguistic laws may give the language an artificial appearance. But, this is not what one means by saying that Sanskrit is an artificial language. By this, it is meant that Sanskrit has ceased to be the mother-tongue of even the Sanskrit speakers and is to be learnt, like Latin, from a teacher.

Sanskrit—an All-Encompassing Language

By this we mean that it has the power to express thoughts of all types : from mythology to literature, from science to philosophy. It has also the sophistication to express the same thought in many ways; what in mathematics is known as 'onto' or 'many-to-one' mapping. For every statement, there is more than one meaning to that statement, and that gives a certain iridescence to the language. This gives rise to prose, poetry, music, dance, etc. It also leads to a process by which imagination is brought in as in mythology. If we concede that mythology is a language, nay, "a higher language that ordinary words cannot express," then Sanskrit language must have a high degree of sophistication since Sanskrit mythology is vast, rich in imaginative symbolism and even profound at times. The same

holds good for philosophy where great subtlety is required in the transfer of information which may span from the most mundane to the most elevated.

Permanence of Sanskrit Language

As a language, Sanskrit has a degree of permanence which no other language has. In olden days, when teaching was oral, there was a need to keep information in tact and pass them on from generation to generation accurately. This led, on the one hand, to a strong emphasis towards versification, poetry and phonetics. On the other side, formulae were devised of inventing and converting words in such a way that chances of distortion were kept at a minimum. After Pāṇini's grammar, Sanskrit language was so much standardised that further linguistic development was not possible. By a general consensus the world over, it is well recognised that Sanskrit literature, as it exists today, is the least distorted of all the languages. The Ṛig-Veda and other literary compositions have come to us as accurately as they were at the beginning.

Encyclopaedic Nature of Sanskrit Language

A great language must reflect the aspirations and thoughts of the people who use it, and should be encyclopaedic in describing the types of possible characters that can exist in the world. In Sanskrit, we have the Rāmāyaṇa and the Mahābhārata where one finds every possible combination of character. There is hardly a character which does not represent some aspect of life, even modern life. The statement in the epic Mahābhārata that यदिहास्ति तदन्यत्र यन्नेहास्ति न तत्क्वचित् is no exaggeration nor the saying व्यासोच्छिष्टं जगत्सर्वम्[3]. The clothes might have been different but the thoughts are identical.

Sanskrit As a Useful Language

We have just seen what makes a language great as opposed to what makes a language useful. Firstly, a language has to be simple if it is to be useful and Sanskrit is a simple language. It was only in the years of its decline that Sanskrit became pedantic, ornate in style and got involved in highly complex forms. It is to the credit of the Sanskrit language that once upon a time, it was not only spoken by a large cross-section of the Indian populace but was also the common language for the whole of the Indian sub-continent despite the multiplicity of languages and dialects. Even today, in India, Sanskrit is a universal language of learning, and is used, in a highly restricted scale, as a medium of literary composition. Further, Sanskrit language had always been full of luxuriant growth of all kinds. From Vedic Sanskrit grew the Classical Sanskrit and from these two have come Pāli and the various dialects of Prākṛit with their local variations. Out of these have evolved, in course of time, the various modern vernacular languages of India. It should be pointed out that while the transition from Vedic to Classical Sanskrit saw minor changes in grammar and vocabulary, similar changes occurred in Pāli and Prākṛit to such a degree that there was a radical change in the character of the language.

Indian Culture

The overall effect of all these is that Sanskrit is just not merely a language: 'It is the poetic testament of the genius of a race and a culture and the living embodiment of the thoughts and fancies that have moulded

them.'[4] It represents a culture, nay, a total integrated†† culture which is known as Indian culture. Indian culture is everything that has come to us from Śrīnagar to Kanyākumarī. There is a common culture in this country which is visible when one studies Sanskrit because the marks of Sanskrit are found everywhere. This culture is so powerful and viable that it has remained alive and unbroken over a period of nearly five thousand years. It is a singular idiosyncrasy of Sanskrit language that the very word संस्कृति means culture.

†† Here, the word 'integration' does not have its usual connotation, but refers to an integration which is more mystical, more encompassing and more transcendental.

Chapter II

SCIENCE IN SANSKRIT

It is not realised by many that Sanskṛit was once a very effective vehicle for conveying scientific thoughts and has a rich scientific literature apart from works of art, philosophy, religion, law, etc. This is particularly true in the areas of mathematics and astronomy, logic and philosophy, physical and medical sciences. We shall, here, make a few points about mathematics and logic.

Sanskrit Logic[5]

Sanskrit or Hindu logic, as a distinct science, is developed in a very advanced way and covers some of the subjects of Nyāya as well as Vaiśeṣika. Starting from ancient times when it was called Ānvīṣikī or the science of debate, and then Nyāya-sāstra or the science of true reasoning (650 B.C. — 100 A.D.), in medieval times (upto 1200 A.D.), it became Pramāṇa-sāstra dealing with pramāṇa, the means of valid knowledge, *i.e.*, perception (pratyaksa) and inference (anumāna). Modern logic (from 900 A.D.) was initially called Prakaraṇa; now it is known as Tarka-sāstra or the science of dialectics. These works contain numerous new technical terms and great subtleties are introduced into their definitions and classification. A complete syllogism consisting of five members or parts (avayava) is given and contains the syllogism of Aristotle as a special case. However, there is always a tendency in Indian logic to give a religious or philosophical base to all

statements which, otherwise, might contain a lot of science. In this context, we refer to Tarkasaṁgraha, a seventeenth century treatise on a Primer of Indian Logic by Annambhaṭṭa. The book[6] is essentially a concise treatise on classification of objects: physical, psychological and sociological. In Table I, we quote three stanzas as translated by the late Kuppuswamy Sastri of Madras (translation A) and give alongside our own translations[7] (translation B) in modern scientific terminology. It is seen that Kuppuswamy Sastri has translated all the words into a philosophical plane rather than a material plane. For example, if we translate the words Dravya, Guṇa, Karma into matter, property and dynamics instead of substance, quality and activity the book sounds modern like any book on physics. In the same way, Utkṣepaṇa and Avakṣepaṇa can be directed motion, and Gamanāni, a random motion which comes in Kinetic Theory. This is not to say that Annambhaṭṭa knew all about Kinetic Theory. He might or might not have known of it, but these are types of motions which are defined and we can get a proper modern version of them. This is something scholars should look for and understand rather than give a philosophical basis to all statements made in Sanskrit literature.

Sanskritic Mathematics

Mathematics in India has a very long history and has always been of a high order. They are usually available in the form of Sanskrit ślokas which combine the conciseness of prose with the rhyme of poetry. We give below a few demonstrative examples.

The theorem known after Pythagoras is stated

in all the śulbasūtras Baudhāyana's (600-500 B.C.) definition is[8] :

दीर्घचतुरस्रस्याक्ष्णयारज्जुः पार्श्वमानी तिर्यङ्मानी च
यत्पृथग्भूते कुरुतस्तदुभयं करोति ।।

'The diagonal of a rectangle produces by itself both (the areas) produced separately by its two sides.'

From the numerical formulae given by some of the Sūtrakāras, approximate values of irrational numbers such as $\sqrt{2}$ (dvi-karaṇī) and $\sqrt{3}$ (tṛ-karaṇī) can be obtained. According to Baudhāyana and Āpastamba (500-400 B.C.)[9] :

प्रमाणं तृतीयेन वर्धयेत्तच्च चतुर्थेनात्मचतुस्त्रिंशोनेन सविशेषः ।।

and according to Kātyāyana (400-300 B.C.)[10] :

करणीं तृतीयेन वर्धयेत्तच्च
स्वचतुर्थेनात्मचतुस्त्रिंशोनेन सविशेषः इति विशेषः ।।

'Increase the measure by its third and this third by its own fourth less the thirty-fourth part of that fourth. The name of this increased measure is saviśeṣa.'

Taking unity as the measure of a square side, we get
$\sqrt{2} = 1 + 1/3 + 1/3.4 - 1/3.4.34 = 1.4142156$
and
$\sqrt{3} = 1 + 2/3 + 1/3.5 - 1/3.5.52 = 1.7320513$
Modern value of $\sqrt{2} = 1.41423562....$ and that of $\sqrt{3} = 1.7320508....$

In the geometry of the circle, Āryabhaṭa I (fifth century A.D.) gave a value for π which is correct to four decimal places in the śloka[11] :

चतुरधिकं शतमष्टगुणं द्वाषष्टिस्तथा सहस्राणाम् ।
अयुतद्वयविष्कम्भस्यासन्नो वृत्तपरिणाहः ।।

'100 plus 4, multiplied by 8, and added to 62,000 : this is nearly the approximate measure of the circumference of a circle whose diameter is 20,000.' This gives, π = circumference/diameter = 62,832/20,000 = 3.1416. This value of π does not occur in any earlier work on mathematics. Note that Āryabhaṭa I has called the above value approximate (आसन्न). In Sadratnamālā, a nineteenth century treatise on astronomy by Sankara Varman, the value of π is given correct to 17 places of decimal[12]. He says : 'In this way, if the diameter of a great circle measures one parārdha (*i.e.*, 10^{17}), its circumference will be 314159265358979324.'

Therefore, $\pi = 3.14159265358979324$

The above are a few sūtras which mention—rather in an ad hoc manner—values of certain fundamental constants without the originators having told us as to how they arrived at these values. Some people assume or even believe that they were arrived at in some mystic ways. But we are certain, there must have been definite reasons behind them. Obviously, their geneces have either been not recorded, or were recorded but lost to posterity.

It would, however, be a misconception on the part of the reader to think that mathematics in India was a series of arbitrary rules alone. There are a number of instances in mathematical literature where actual theorems have been given along with how they were developed. An example is the lemma (भावना) of Brahmagupta for integral solutions of the indeterminate equation of second degree (varga-prakṛti)** using

** This is of the form $Nx^2 \pm k = y^2$. Here, the coefficient N is termed guṇaka prakṛti, x kaniṣṭha pada, hrasva-mūla or ādya-mūla, y jyeṣṭha-pada, jyeṣṭha-mūla, or anya-mūla, k kṣepa, prakṣepa or prakṣepaka.

interpolator[13] :

मूलं द्विधेष्टवर्गाद् गुणक गुणादिष्टयुत विहीनाच्च ।
आद्यवधो गुणकगुणः सहान्त्यघातेन कृतमन्त्यम् ।।
वज्रवधैक्यं प्रथमं प्रक्षेपः क्षेपवधतुल्यः ।
प्रक्षेपशोधकहृते मूले प्रक्षेपके रूपे ।।

'An optional number added to or subtracted from the product of the square of a number and an optional multiplier yields a square root. (Carry out the operation twice and set one below the other.) The product of the two first or lesser roots multiplied by the multiplier and then added to the product of the two last or greater roots gives the last or greater root. The sum of the cross-products of the first and the last roots gives the first root. Similarly, the interpolator will be the product of the (two) interpolators. For (finding the roots of the equations with) unity as interpolator, divide the roots by the square of the interpolator.' Brahmagupta lived in seventh century A.D. The type of equation with interpolator, later, came to be known as Pellian equations. John Pell lived in seventeenth century A.D., while a thousand years earlier, such equations were dealt with with accurate terminology in India. Later, to solve second degree equation of the above type, Bhāskara II (twelfth century A.D.) proposed a method he termed cakravāla and stated it as follows[14] :

ह्रस्वज्येष्ठपदक्षेपान भाज्यप्रक्षेपभाजकान् ।
कृत्वा कल्प्यो गुणस्तत्र तथा प्रकृतितश्च्युते ।।
गुणवर्गे प्रकृत्योनेऽथवाऽल्पं शेषकं यथा ।
तत् तु क्षेपहृतं क्षेपो व्यस्तः प्रकृतितश्च्युते ।।

गुणलब्धिः पदं ह्रस्वं ततो ज्येष्ठमतोऽसकृत ।
त्यक्त्वा पूर्वपदक्षेपाँश्चक्रवालमिदं जगुः ॥

'The lesser root, the greater root and the interpolator are to be regarded as the dividend, the additive quantity and the divisor respectively (as in the kuṭṭaka). The multiplier (of the kuṭṭaka) is to be so chosen that its square less the prakṛti or vice versa is the least. This (least) quantity divided by the interpolator is the interpolator (of the new equation); its sign will be reversed if the square of the multiplier be subtracted from the prakṛti. The quotient (of the kuṭṭaka) corresponding to the multiplier is the lesser root. From this the greater root (is obtained). Putting aside the former roots and the interpolator, the same process is to be repeated (to obtain similar sets of values and so on). This is called the cakravāla.'

The method seeks to derive from the equation

$$Na^2 + k = b^2$$

the equation

$$N\left(\frac{am + b}{k}\right)^2 + \frac{m^2 - N}{k} = \left(\frac{bm + Na}{k}\right)^2$$

where, m is the multiplier determined by the kuṭṭaka method so that $m^2 - N$ is the smallest and $am + b$ is divisible by k, the quotient $\frac{am + b}{k}$ being the lesser root. Note that the pulverizer is formed by taking the lesser root a as the dividend, the greater root b as the additive quantity and the interpolator k as the divisor, as stated in the first line of the rule above.

Bhaskara II's cakravāla or cyclic method has been described by no less a physicist and mathematician than Hankel as 'the finest thing achieved in the theory of numbers before Lagrange.'

Āryabhaṭa I gave for the sidereal period of earth's rotation about its axis a value which is astonishingly close to the modern one. This is obtained from the number of eastward rotations of the Earth in a Yuga as stated in part of a śloka as follows[15] :

युग····कु ङिशिवुण्लृष्खृ प्राक् ।

'In a Yuga, the eastward rotations of the Earth are 1,58,22,37,500.'

∴ Sidereal period of earth's rotation

$$= 1577917500/1582237500 \text{ days}$$

$$= 23^h\ 56^m\ 4^s.1$$

Corresponding modern value

$$= 23^h\ 56^m\ 4^s.091$$

The numerical values borne by the letter chronograms of the preceding verse have been deciphered using Āryabhaṭa I's rule on the alphabetical system of expressing numbers[16] :

वर्गाक्षराणि वर्गेऽवर्गेऽवर्गाक्षराणि कात् ङमौ यः ।
खद्विनवके स्वरा नव वर्गेऽवर्गे नवान्त्यवर्गे वा ॥

There was also prevalent in India another system of word-numerals devised by Bhāskara I (seventh century A.D.). It is reproduced in Table II from reference (17).

Chapter III

HISTORY OF INDIAN SCRIPTS

We have so far discussed, in brief, about Sanskrit language and Sanskritic science and have seen their virtues and benefits. We shall now look at a slightly different but allied subject, namely, Indian scripts and their evolution purely from the scientific point of view. It is commonly taken for granted that Sanskrit and Devanāgarī scripts are one-to-one in correspondence, that they are identical. This is not quite true. Devanāgarī script is of comparatively recent origin when we come to think of other Indian scripts and their history.

In the beginning, there was only the Brāhmī script in India and from this have evolved, over a period of time, almost all the Indian scripts including Devanāgarī. Tables III and IV show that Telugu, Kannaḍa and Brāhmī scripts are identical except for a wriggle here, a wriggle there depending on the leaf, on the parchment and on the writing material used. Even Tamil (Table V) is seen to have the same origin in most of its letters.

Table VI shows the evolution of 'Ka'. In the Mauryan script of second century B. C., it is just a cross. In the second line, it is still the same cross but with a little wriggle, and the family goes on. If in making the 'Ka', we do not lift the finger, it makes a round and the 'Ka' of Devanāgarī is finally reached on the left hand bottom of the table. It is noted that at about the Chālukyan period from where the Kanarēse starts, the round 'Ka' has appeared. Further down the line from

where the Rāshtrakūṭā starts, the 'Ka' is no different from the present 'Ka' in Devanāgarī. Though the Tamilian change is to the other side, the final 'Ka' in Tamil that has come from the Chōla period is quite similar to the 'Ka' of Devanāgarī. The differences between the various 'Ka's are dependent primarily on how well the lines were made. Therefore, the scripts are identical. Table VII shows the evolution of 'Ga'. To start with, it is an inverted 'V'. As time passes, Devanāgarī 'Ga' comes on the left side and, the Kannaḍa 'Ga' gets a top flourish to make it even with the other scripts.

Table VIII gives the origin of 'Ṭa' which is like a 'C' to start with. It continues to be a 'C' at the bottom except that it has got a line on the top. It becomes very complicated in Telugu and Kannaḍa and has developed a wriggle in the lower middle. Though the 'Ṭa' in Kannaḍa looks very round, one can see the connection between the two except the flourishes.

Table IX gives a diagrammatic representation of the evolution of 'Ma'. At the beginning, it is a 'U' with a zero attached to its bottom; but with the passage of time, it is gradually transformed into the present 'Ma'. It is changing all the time with minor changes occurring from century to century and finally it looks very different. The Kannaḍa 'Ma' has directly come from the same source except for the flourishes. And as for the Vijayanagar 'Ma', it looks rather close to the Tamil type because script origin is the same. In the last column on the top, in one Tamil phase, the 'Ma' corresponds to the Mauryan period indicating thereby that there might have been a connection between the two.

But, whether it was from South to North or vice versa, it is difficult to say.

Table X tells how the present 'Ya' of Devanāgarī has come over a period of time from the original 'Ya' which looks like an inverted arrow. The complicated looking 'Ya's are of Kannaḍa and Vijayanagar scripts. The Tamil 'Ya' at the top right is very interesting and looks like an inverted arrow except that the wings have gone up. In South India, it is called a 'Murnama'. Its growth can be seen down the Table. The next two Tables are for 'La' and 'Va' respectively. We leave them to the readers to trace their evolution.

Chapter IV

SCRIPT REFORM AND PROPOSITION OF A NEW SCRIPT

We have seen that Indian scripts have more or less a common origin. Not only that, the scripts are also scientific having been developed over centuries in different parts of India. For example, 'Ḍa' (ड) and 'Ṅa' (ङ) look alike except for one dot but there is no phonetic connection between the two. Also, computers have come to stay in our society in a big way. All these may mean that time is ripe in India for a script reform. We do not know if a script reform will ever be implemented in practice, but we will make an attempt towards this in this paper with the spirit that it will simplify Indian languages and help villagers learn the script faster.

Table XIII (last row) shows the simplified vowel terminations in the script proposed by us. They have been derived from the Devanāgarī script in two/three steps. Second row shows that all the vowels can be obtained from the letter 'a' (अ) with minor modifications. After 'a' just one line and we get 'ā' (आ); 'i' (इ) is 'a' followed by a 'ႶΩ', 'ī' (ई) is 'a' followed by 'm'; 'u' (उ) and 'ū' (ऊ) are 'a' followed by 'U' and 'w' respectively. Derivation of rest of the characters are self-explanatory. The vowels are separated out completely in the third row and a little more simplification leads to the final vowel terminations in the last row. The combination that we, by this process, get is ⊣, H, ∩, m, U, w, etc. One can see some aspects of

Tamil language here. We will use this simplified script because it is easy to follow and when any of these vowel terminations are used after a consonant, the corresponding vowel effect is obtained.

In Table XIV are presented consonants and the consonants with vowel endings both in the new script as well as in the Devanāgarī script. We have the usual 'k' (क्), but the 'kh' is just a 'k' with a wriggle and the same procedure is followed for all the Varga letters from क् to म् . This approach automatically reduces many characters and as in Tamil script, 'k', 'kh', 'g' become identical. The rarely used ṅ (ङ) and ñ (ञ्) can be the same type of ṇ (ण्) except for two dots and one dot respectively. Written this way, 'k' (क्), 'c' (च्), 'ṭ' (ट्), 't' (त्), 'p' (प्) are the only new characters and the rest are simply modified around each of them because phonetically they are similar. As in Tamil, whether we say 'Adbhuthanathan' or 'Athbhutanathan', they are the same thing because the phonetics is so close that it does not matter. Finally, 'y' (य्), 'r' (र्), 'l' (ल्), 'v' (व्), 'ś' (श्), 'ṣ' (ष्), 's' (स्) and 'h' (ह्) are suitably modified to simplify the whole alphabet.

Table XV shows how a Sanskrit verse—actually half a verse—looks in the original, in the new script and in a script made in straight lines for the computer. This śloka—taken from Ādi Śankara's "Bhaja Govindam"[18]—is befitting to the present article because we started with Pāṇini and grammar and this particular śloka refers to grammatical rules. It means : "At the time of death, the rules of grammar profit nothing." Whatever it is

that Śankarāchāryā wanted to say, we interpret it as follows : the rules of grammar do not profit anything when one knows them only towards the end. The middle one in the table shows how the śloka looks in the new script. Obviously, the proposed script is not the ideal one. The bottom one is the computer version in straight lines. Though it looks very different, it is devised directly from the original Devanāgarī with the advantages that have already been pointed out.

Chapter V

SUMMARY AND CONCLUSIONS

We have travelled a long way from Pāṇini to modern Indian scripts and then script reform. We have proposed a new script which has reduced the number of characters in the Devanāgarī from fifty to about twenty-six. The script has been shown to be adequate for purposes of running handwriting and has the potentiality of being adapted to all the Indian languages thereby paving the way for their unification. However, we do not suggest that we follow this script. We are only telling that this is one of the possibilities and scholars should think about this.

The sūtra method constitutes an alternative method of expressing scientific terminology, particularly mathematics and requires thorough examination because it seems to be simple, more compact than, and as accurate as the symbolic method that is currently in use.

We conclude the article with a quotation[19] which says :

सर्वथा व्यवहर्तव्यं कुतो ह्यवचनीयता

यथा स्त्रीणां तथा वाचां साधुत्वे दुर्जनो जनः ॥

'By all means, one must speak out since it is impossible to placate all critics. In estimating the excellence of a speech (or literary work), as in judging the purity of women, the world is always harsh.'

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Table I: THREE STANZAS FROM *TARKASAMGRAHA* AND THEIR TRANSLATIONS

SANSKRIT	TRANSLITERATION	TRANSLATION A	TRANSLATION B
Verse 2			
द्रव्य	Dravya	Substance	Matter
गुण	Guṇa	Quality	Property
कर्म	Karma	Activity	Dynamics
सामान्य	Sāmānya	Generality	Intersection with sets of properties of all other matter
विशेष	Viśeṣa	Particularly	Disjoint set of properties with respect to other matter
समवाय	Samavāya	Inherence	Internal structure
अभाव	Abhāva	No existence	Non-material form, Null set
Verse 3a			
पृथ्वी	Pṛthvī	Earth	Solid
आपः	Āpah	Water	Liquid
वायु	Vāyu	Air	Gas
तेजस्	Tejas	Light	Radiation
आकाश	Ākāśa	Ether	Ether
काल	Kāla	Time	Time
दिक्	Dik	Space	Space
आत्मन्	Atman	Soul	Soul
मनस्	Manas	Mind	Mind (consciousness)
Verse 3c			
उत्क्षेपण	Utkṣepaṇa	Upward motion	Directed motion (vector)
अवक्षेपण	Avakṣepaṇa	Downward motion	
आकुञ्चन	Ākuñcana	Contraction	
प्रसारण	Prasāraṇa	Expansion	
गमनानि	Gamanāni	Going from place to place	Random motion

Table II: WORD-NUMERALS USED BY BHASKARA I

Numeral	Word-numeral
0	अभ्र, अम्वर, आकाश, ख, गगन, नभ, पूर्ण, विन्दु, वियत्, विहायस्, व्योम, शून्य ।
1	अमृतसन्मयूख, इन्दु, उडुप, चन्द्र, चन्द्रक, धरा, निशाकर, निशानाथ, प्रालेयरश्मि, रूप, शशाङ्क, शशि, शालिन्, शीतकिरण, शीतरश्मि, शीतांशु, सुधामयूख, हिमांशु ।
2	अश्विन्, दस्र, नयन, नेत्र, पक्ष, वाहु, यम, यमल, युगल ।
3	अग्नि, कृशानु, गुण, दहन, पावक, पुष्कर, राम, लोक, वह्नि, विक्रम, विष्णुक्रम, शिखि, हुताशन ।
4	अब्धि, अम्बुनिवह, अम्भोधि, आपगानाथ, उदधि, कृत, जलधर, जलधि, पयोधर, वेद, समुद्र, सागर ।
5	अक्ष, अर्थ, इन्द्रिय, इषु, तन्मात्र, वाण, भत, विषय, शर, शिलोमुख, सायक ।
6	अङ्ग, ऋतु, रस ।
7	अग, अचल, अद्रि, ऋषि, क्षितिधर, क्षितिभृत, क्षोणीधर, क्ष्माभृत्, गिरि, तापस, दिविचर, धात्रीधर, नग, पर्वत, भूधर, भूभृत्, महीभृत्, मुनि, शिलोच्चय, शैल, स्वर ।
8	कुञ्जर, गज, नाग, पन्नग, प्रकृति, भुजग, भुजङ्ग, मतङ्गज, वसु ।
9	अङ्क, छिद्र, नन्द, रन्ध्र ।
10	आशा, ककुभ्, दिक्, पङ्क्ति ।
11	भव, रूद्र, शिव ।
12	अर्क, इन, तिग्मांशु, नर, भास्कर, रवि, सूर्य ।
13	विश्व ।
14	मनु, शक्र, सुराधिप ।
15	तिथि, दिन ।
16	अष्टि ।
18	धार्तव, धृति, धृतिक ।
20	नख ।
24	जिन, सूक्ष्मकाः ।
25	तत्त्व ।
27	ऋक्ष, नक्षत्र, भ ।
30	तिथि ।
32	दन्त ।
48	संस्कार ।

Table III

DEVELOPMENT OF INDIAN SCRIPTS (BRĀHMĪ)

KEY

Table IV

DEVELOPMENT OF INDIAN SCRIPTS (CANARESE-TELUGU)

Table V

DEVELOPMENT OF INDIAN SCRIPTS (GRANTHA-TAMIL)

Table VI

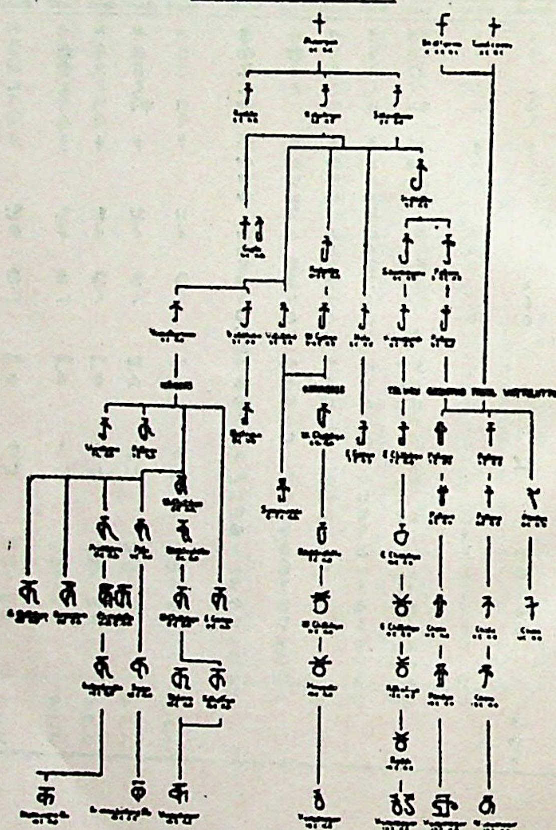


Table VII

THE STORY OF INDIAN SCRIPTS

THE EVOLUTION OF GA

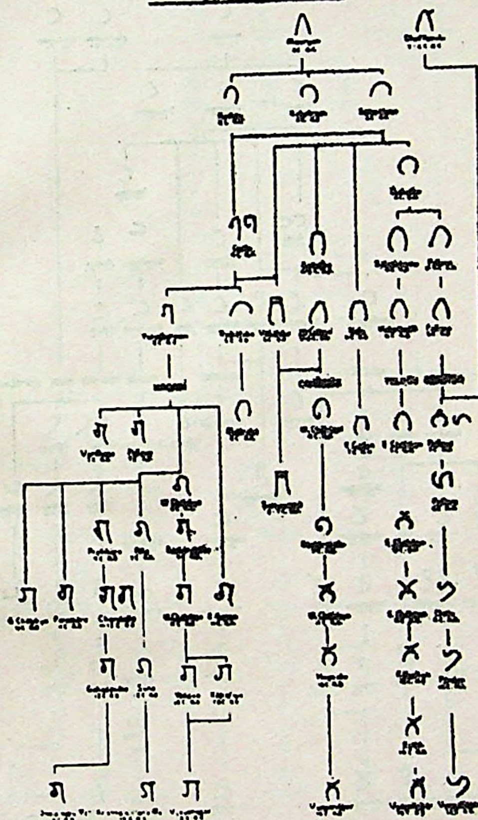


Table VIII

THE STORY OF INDIAN SCRIPTS

THE EVOLUTION OF *TA*

Table IX

THE STORY OF INDIAN SCRIPTS

THE EVOLUTION OF *MA*

Table X

THE STORY OF INDIAN SCRIPTS

THE EVOLUTION OF य

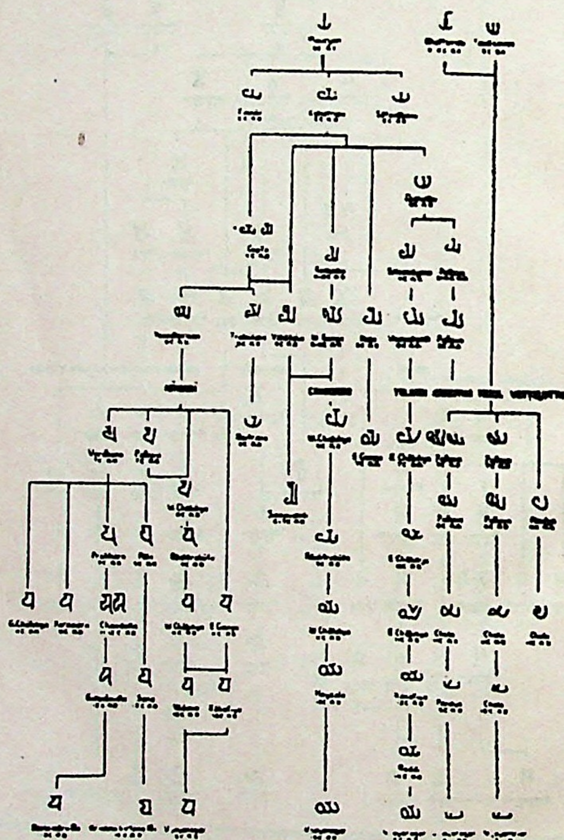


Table XI

THE STORY OF INDIAN SCRIPTS

THE EVOLUTION OF *LA*

Table XII

THE STORY OF INDIAN SCRIPTS

THE EVOLUTION OF VA

NAGARI

CANARESE

TELUGU

GRANTHA

MAL. VATTELUTTU

Table XIII

VOWELS IN THE PROPOSED NEW SCRIPT

HINDI ALPHABET	अ	आ	इ	ई	उ	ऊ	ए	ऐ	ओ	औ	अं	अः
BASE CHARACTER	अ	आ	अ∩	अm	अu	अw	अे	अै	आे	आै	अं	अः
MODIFIED VOWEL TERMINATION	⊣	–H	–∩	–m	–u	–w	⊣̀	⊣̀́	–H̀	–H̀́	⊣̇	⊣:
SIMPLIFIED VOWEL TERMINATION	⊣	H	∩	m	U	w	⊣̀	⊣̀́	H̀	H̀́	⊣̇	⊣:

Table XIV

CONSONANTS AND CONSONANTS WITH THE VOWEL ENDINGS IN THE PROPOSED SCRIPT

	क	का	कि	की	कु	कू	के	कै	को	कौ	कं	कः
[illegible] (क्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ख्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ग्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (घ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ङ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (च्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (छ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ज्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (झ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ञ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ट्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ठ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ड्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ढ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ण्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] (ध्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] (प्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (फ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ब्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (भ्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (म्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] (र्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (ल्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] (ष्)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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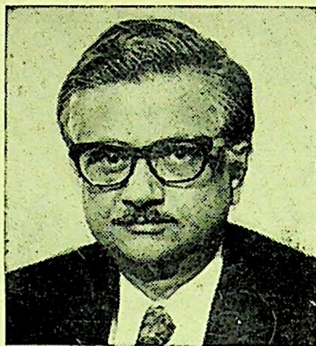
Table XV

TRANSLITERATION IN THE PROPOSED SCRIPT OF A SANSKRIT VERSE IN DEVANĀGARĪ

संप्राप्ते सन्निहिते काले
न हि न हि रक्षति डुकृञ्करणे ॥
(ORIGINAL VERSE)

[illegible]
[illegible]
(IN THE PROPOSED SCRIPT)

[illegible]
[illegible]
(COMPUTER VERSION IN THE PROPOSED SCRIPT)



ABOUT THE AUTHOR

Dr. Raja Ramanna is a versatile personality.

His present exalted position of Chairman of India's Atomic Energy Commission is well-deserved recognition of his immense contribution to the field of science, particularly Nuclear Physics.

Dr. Ramanna has done research in Neutron Physics and Nuclear Physics with special reference to nuclear fission and has participated in many international conferences at the U. N. level on the peaceful uses of atomic energy—he was Chairman of several related committees—National and International.

Though a scientist of world renown, Dr. Ramanna has a deep-rooted faith in the spiritual wisdom of India.

Dr. Ramanna is also the Chairman of the Science and Technology section of the Ancient Insights and Modern Discoveries project of Bharatiya Vidya Bhavan from its inception in 1977.

Bharatiya Vidya Bhavan is happy to bring out this book, being the text of his lecture on "Sanskrit and Science" which he delivered under the auspices of the Department of Ancient Insights and Modern Discoveries.